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UNIVERSITY OF LONDON.

REV. DR. LARDNER'S
INTRODUCTORY LECTURE.

SECOND EDITION.

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A DISCOURSE

ON THE ADVANTAGES OF

NATURAL PHILOSOPHY AND ASTRONOMY,

AS PART OF A

GENERAL AND PROFESSIONAL EDUCATION.

BEING AN

Introductory Lecture

DELIVERED IN

THE UNIVERSITY OF LONDON,

ON THE 28TH OCTOBER, 1828,

BY

THE REV. DIONYSIUS LARDNER, LL.D. F.R.S. L. AND E.

PROFESSOR OF NATURAL PHILOSOPHY AND ASTRONOMY IN THE
UNIVERSITY OF LONDON, M.R.I.A. HONORARY FELLOW OF THE
CAMBRIDGE PHILOSOPHICAL SOCIETY, FELLOW OF THE
ASTRONOMICAL SOCIETY, HONORARY MEMBER OF
THE SOCIETY FOR PROMOTING USEFUL
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PREFACE.

The following is the First of two introductory Lectures which were delivered on the opening of the School of Natural Philosophy in the University of London. Neither the favourable reception which this Discourse met with from an over-indulgent audience, nor even the unexpected demand for its repetition, would have induced the Author to venture its publication, had it not happened that numerous persons who were desirous to be present at its delivery, and who had obtained tickets of admission, were excluded, on both occasions, from want of room. As the Second Lecture was devoted to the exhibition of the splendid Apparatus which has been provided for this class, and to the explanation of its uses and advantages in the business of instruction, it is obviously a subject not suited for publication. It may not be improper, however, here to state a few particulars respecting it.

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The Apparatus may be divided into four classes. The first comprises instruments of philosophical investigation, such as Air-pumps, Balances, Electrical and Galvanic machines, and apparatus for experiments in all parts of physical science. Neither attention nor cost has been spared to provide these not only in number and variety, but also in magnitude and excellence, equal, if not superior, to any collection in these kingdoms.

The second class includes Working Models of machines, on a scale adapted for exhibition in a large theatre, to a class as numerous as that which may be expected in the University of London.

It often happens that an instrument of which the use and application are to be taught, is too delicate for the rough manipulation of the lecture-room, and even though it should be produced, its parts might be too minute to be shown advantageously to a class. This remark applies very generally to instruments of philosophical observation, but more especially to those used in the departments of Astronomy and Geodæsy. In these cases well executed Models in Wood have been prepared, in which all the usual adjustments and minuter parts are exhibited on a larger scale and of less delicate construction. Such models form the third class of apparatus.

The last class comprises, *Sectional Models.* The construction of these instruments is a subject to which Dr. Lardner has given considerable attention, and he hopes to prove that they are now brought to a state of perfection, which entitles them to be considered the most powerful instruments of instruction which modern times can boast.

In order to represent a machine in this way, it is only necessary so to transpose the different parts, that while their mechanical connection is preserved, they will be brought into the same plane. As the object is to explain the principle of the construction and operation of the machine, it is not necessary that the proportions should be rigidly observed in the model; and in many instances it will be absolutely necessary to depart from them. In this respect, the following rules may be observed. The smallest part whose action is to be explained, should be made sufficiently large to be visible in every part of the theatre or class-room, and the largest parts of the machine limited to that magnitude which will prevent them from becoming inconvenient and unwieldy. Subject to these conditions, the scale and proportions of the parts of the model are as nearly as possible the same with those of the machine. When an invisible agent, such as air, or steam, is engaged in a machine, it cannot of course be made to appear in the model; but the valves, pistons, or other parts of the machinery which it affects, are moved in the same manner by invisible threads or wires, so that every motion and change which takes place in the machine, also appears in the same manner and at the same moment in the model. Such instruments as these are, in machines, analogous to the dissection of the subject in anatomy, but they attain their end much more perfectly. Dissection can only exhibit the form and arrangement of the different parts, but does not exhibit their motion. These models more resemble what the anatomist would obtain if he could remove the skin and integuments from the living body, and disclose the blood circulating, the heart and pulse beating, the lungs playing, and all the functions of life in full operation.

In cases where the instrument or machine which is to be explained, is not of sufficient importance to warrant the expense or bulk of a model, delineations on a large scale are provided. In such instances, two drawings generally are prepared; the one exhibiting a section of the instrument, adapted to explain its construction and operation; and the other conveying in perspective a representation of the arrangement of its parts.

The mathematical details of physical science are also represented on canvass, in characters sufficiently large to be observed from every part of the theatre; by which means, the most numerous class may be taught, and with as much ease and clearness as a single student.

University of London,
November, 1828.

INTRODUCTORY LECTURE.

Gentlemen,

The department of the University, the opening of which you have this day honoured by your presence, embraces branches of public instruction which have ever held a prominent place in academical institutions. But there certainly never was a period at which they ought to stand so conspicuous as the present, because no preceding age has been so largely indebted to them for the luxuries and substantial comforts of civilized life; nor is there any country on the face of the globe which owes to them so much prosperity and power, as that which we inhabit. When we consider the extent of the sciences which fall within the province of this professorship—an extent which is only surpassed by the importance of those sciences, as branches of general as well as of professional education; when we contemplate the benefits which must spring from the successful establishment of a great school of Natural Philosophy in the most populous and wealthy city in the world—benefits affecting not the present race only, but unborn millions; it is impossible not to feel deeply and express strongly, the heavy responsibility which must attach to him whose practical duty it is to realize a design so noble. Under all these circumstances, I shall esteem myself fortunate indeed, if the quality of the instruction which shall be imparted in this Theatre, be found in any degree commensurate with the magnitude and importance of the subject, and with the splendour and even luxury of the apparatus and other accessories furnished by the munificence of the founders of this University.

Natural Philosophy is a general name, under which are comprised two principal species, Mechanical and Chemical Philosophy. Either because of the greater extent of the science, or the higher order of reasoning applied in it, the term " Natural Philosophy" is now used *par excellence*, synonymously with Mechanical Philosophy. The line which separates Mechanical and Chemical Philosophy is easily drawn. The phenomena contemplated in the former, always have reference, either directly or indirectly, to the arrangement, collocation, or juxta-position of bodies, or the parts of bodies with respect to each other, whether these bodies be placed upon the surface of the earth, and are subjects of immediate experiment, or are found in the abyss of space in which the earth itself rolls, and therefore, objects only of distant observation. The Chemical Philosopher, on the other hand, contemplates changes and effects which do not depend, or rather are not perceived to depend, on mere arrangement, or juxta-position of parts; changes which seem to affect the very nature of the bodies engaged, and in which some leading and essential qualities appear to be obliterated, and others called into existence. It is certain, that many of these phenomena arise from mechanical causes, and probable that all do so; but until they be demonstratively traced to such a source, they properly belong to the province of the chemist.

If two pieces of lead, or two plates of well-polished brass, be brought into close contact, they will adhere so strongly that the exertion of considerable force will be necessary to separate them. This is a mechanical phenomenon, manifested by the contiguity or contact of two solids. If, on the other hand, a piece of potassium be brought into contact with ice, flame is instantly produced: here is something very different from arrangement or collocation of parts. This phenomenon is chemical. Again in fluids: if oil be put into the same bottle with water, it will float at the top, the one liquid being yellow, the other colourless. If the bottle be shaken, the particles of the oil will be simply intermingled with those of the water, and a faint yellow liquid will be produced, until the components again separate. This is a mechanical phenomenon. On the contrary, lime water and a solution of corrosive sublimate are both colourless fluids; but if they be mixed, an opaque brownish yellow liquid is produced; and if to this mixture some sulphuric acid be added, the opacity and colour will again disappear, and a transparent colourless liquid will be obtained. These are chemical phenomena.

In the one case, the sensible qualities of the components are found in the compound, modified and diluted. In fact, no other change ensues, than the diffusion of the particles of the one substance through and among those of the other. In the other case, the effects are wholly different. Leading sensible qualities of the components are obliterated; others of an entirely different character appear. The combination is therefore, in this case, said to be chemical; in the former, mechanical. Now, some are of opinion, that the sensible qualities of substances depend on the size and figure of their ultimate and elementary molecules. If this be true, it is possible, that by the coalition of the molecules of one substance with those of another, new molecules may be formed for the compound, differing in size and figure, and therefore producing different sensible qualities from those of the components. Were this conclusively established, and the figure of the molecules producing determinate effects upon the senses defined, the phenomena in question would at once be transferred from the Chemist to the Mechanical Philosopher; and, such must be the effect of the progress of knowledge. Mechanical Philosophy will constantly encroach on the territory of Chemistry; while Chemistry, on the other side, pushes her conquests into the *terra incognita* of Nature.

Mechanical Philosophy stands between Pure Mathematics and Chemistry. As a branch of general education, it possesses considerable advantages over each of these departments of science. Like Chemistry, it is based upon facts established by accurate experiment and observation; but these facts, like mathematical axioms, are few in number, and simple in character. The superstructure raised upon them is strictly demonstrative; and consequently, in passing from a first principle or physical axiom, to the most remote or abstruse conclusion, we do not lose one grain of the certitude of the principle from which we departed. If that principle be certainly true, the inference which we deduce from it, however remote, must be equally so. This is an advantage which no science has, or can have, which does not admit of the application of mathematical reasoning.

Compared with Pure Mathematics, Natural Philosophy must be admitted to have less certainty, because the facts which it assumes as first principles, are of a more complex character, and not such frequent and obvious subjects of observation. But this inferior rigour is more speculative than real, and accordingly we find few, except Mathematicians, who can see the difference between the degrees of evidence of a mathematical and physical axiom. An example will make this apparent. That two magnitudes which exactly cover the same magnitude, would exactly cover each other, is a mathematical axiom. The certainty of this and similar truths is considered to be the highest of which our nature is susceptible. That the Sun which rose and set at London yesterday, and every preceding day within human record, will rise and set to-morrow; that Fire, which burned the hand of Mutius Scævola, would also under the same circumstances burn mine; are physical axioms. To institute a distinction between the degrees of certainty of such propositions, must seem to minds not imbued with scholastic habits, little better than quibbling.

In the present Lecture, Gentlemen, I propose to lay before you a brief outline of the subjects of instruction which have been appropriated to this Professorship, and to take a view of the advantages of these, first, as part of a liberal education; and secondly, as an essential element in the education of those destined for particular professions. In the Lecture of to-morrow, I shall explain the order and method which will be adopted in teaching these sciences; and shall more especially bring under your attention the instruments of illustration of which I intend to avail myself.* I shall anxiously seize that opportunity, to exhibit to the public some of the magnificent apparatus which has been provided for this class, to explain its use, and show its actual operation. Among these, I may more especially mention several beautiful working and sectional models of Steam-engines.

In Mechanical Science, several properties and forms of bodies are considered, and according to these forms and properties, the science is divided and arranged. The mutual action of solid bodies placed on the surface of the earth, is the first and most obvious subject which solicits our attention. The department of the science which is devoted to this investigation is commonly called Mechanics. On many accounts, this is one of the most important divisions of Physics. Solid bodies are generally the most convenient and effectual means of transmitting and modifying force, and are therefore the materials of which most machines are formed. They are also the most ready and efficient means of opposing passive resistance to incumbent pressure, and are therefore the materials of which structures are composed.

Besides this, the principles and properties developed in the examination of solid bodies on the surface of the earth, are by no means peculiar to those bodies, or to the situation in which they are placed. Many of them are laws and properties common to matter, whatever form it may assume, or in whatever situation it may be found. Under this division of Physics will be included the consideration of extension, divisibility, mass, density, porosity, inertia, attraction, weight, motion, and force. The elements of Machinery, or, as they are called, the "Mechanic Powers," will be examined in considerable detail. Friction, and the resisting forces, the strength of materials, the force of animals, and other collateral topics, will be investigated. These will be the subjects of our first course.

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* The subject of this second Lecture is, for obvious reasons, not suited for publication.

In another course, the attention of the student will be directed to the properties of fluids, inelastic and elastic; that is, in the liquid and gaseous (or vaporous) states. These form the subjects of the divisions of physical science, which are commonly denominated Hydrostatics, Hydraulics, and Pneumatics.

Having developed the laws and principles which regulate the action of bodies on the surface of the earth, our views will next be directed to the heavens. The various appearances and phenomena there exhibited will be exactly defined, and the methods of observing them explained. Hence, by a chain of strict reasoning, the motions and magnitudes, which cause these appearances, will be detected. Such are the limits of Plane Astronomy.

Proceeding one step further, the peculiar laws of these motions will be explained, and the forces which regulate them discovered. And here, we shall have occasion to observe the perfect identity of these results with the laws previously found to prevail on the surface of the earth; plainly proving that the same hand which guides the fall of a rain-drop, also controls the planet in its path, governs the devious and eccentric evolution of the comet, and compels the gyration of the unwieldy orb of the Sun around the centre of the system. Such are the lofty contemplations of Physical Astronomy.

Connected with this, is the less sublime though not less useful problem, to determine the figure and dimensions of the various parts of the planet on which we live. Such have been the extent and accuracy to which modern Physics has attained, that this single problem has assumed the form of a separate science, under the name of *Geodæsy*.

Vast as the subjects are, of which I have here attempted to sketch the outline, they constitute little more than half the extent of the science to be taught in this theatre. The agents engaged in these investigations, are all of a massive and ponderous character. Even the subject of Pneumatics, Air itself, is as impenetrable as adamant, and possesses the ponderous principle as essentially as lead. A far more subtle class of agents remains to be considered: agents which are denominated imponderable, because the most delicate tests have never detected in them either weight or inertia: such are Light, Heat, Electricity, and Magnetism.

Optics is the name generally applied to that division of Natural Philosophy which treats of the properties of Light. The use of this term would, however, be more correct, if its application were restricted to that part of the science which more immediately relates to the theory and phenomena of Vision. Sight is not only the most perfect, but also the most useful and pleasurable of the senses. It is the most perfect, because the impressions received through it are the most vivid and exact. It conveys to us ideas of light and colours, and through their means, the most distinct and accurate perceptions of form and figure, space, distance, and motion. It is the most useful, because it informs us of changes and events which happen in places where we are not present, and thus endows us with a degree of ubiquity. It is the most pleasurable not only because of the infinite variety of the ideas which it furnishes, and the wonderful richness of colours, for which it is the only avenue; but even *light* itself, exclusive of any of the objects which it renders visible, produces one of the most agreeable of all sensations. This is manifested by the eagerness with which the new-born infant directs its eyes to the quarter from whence light proceeds. Numerous instances have occurred of persons deprived from infancy of the sense of sight, whose greatest enjoyment was to gaze for hours at a light so strong, as to excite a feeble sensation in their imperfect organs.*

If the consideration of Vision and its immediate objects be interesting, the astonishing mechanism by which art has improved that sense, already so perfect, and even supplied it where it has been refused by nature, is not less so. Who is so destitute of curiosity, so dead to every sense of admiration for the godlike results of human genius, as not to seek a knowledge of that science, which, usurping the functions of a miracle, restores sight to the blind; repairs, in the most important respect, the ravages of time; and if it raise not the dead, at least prolongs those enjoyments, without which life would become a burthen? To notice all the attractions presented by this most fascinating branch of physics would far exceed our present limits. I shall not, therefore, attempt to enumerate the wondrous powers which we receive from the telescope and the microscope. With the one, sweeping through regions of the universe, whose distances and magnitudes far transcend the power of imagination to conceive, and even baffle the power of number to express: with the other, penetrating the minute and secret recesses of nature, and beholding worlds of organized living beings in a single drop of liquid. Setting aside all these considerations, in which Vision is directly engaged, the results of modern investigations have given a new aspect to the science of Light, and the name Optics has now become altogether inadequate.

It is impossible to contemplate the recent discoveries respecting Light, without sentiments of admiration and astonishment: admiration at the gorgeous phenomena produced by its action upon the bodies on which it impinges and which it penetrates; at the infinite and apparently capricious varieties of which these appearances are susceptible; and, above all, at the simplicity and beauty of the mechanical laws which govern this extraordinary fluid: astonishment at the sagacity which has threaded this labyrinth, which has disentangled this complexity, and which has discovered, amid apparent irregularity, all that harmony which would be immediately perceived in them by beings of a superior order.

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* Mr. Herschell notices this circumstance in his Treatise on Optics.

The effects of these improvements in the theory of Light have not terminated in that science. They have spread their influence into Mineralogy. Polarized Light has given us new and infinitely refined perceptions of touch. We are enabled, with mathematical precision and with demonstrative certainty, to assign the exact form of atoms millions of times beyond microscopic power. We tremble upon the brink of discovering the elementary constitution of the material world. We can feel, as it were, the molecules of Light itself, the most subtle of all fluids; we can almost perceive their sides and ends, and can actually control, regulate, and arrange the constituent parts of a sunbeam.

The nature and properties of Heat, a subject which stands between Natural Philosophy and Chemistry, is on the confines of both, and may be considered a sort of debatable land, or rather a common territory. Heat decides the form of a body, whether it be solid, liquid, or vaporous. It is also an essential element in the determination of magnitude, since a change of temperature is generally accompanied by a change of bulk. Heat partakes of several properties of Light; it is refracted and reflected by analogous laws. It is the principal agent in the most important mechanical invention of this or any former age. On all these accounts, it is right that Heat, its nature, properties, applications, and uses, should hold a prominent place in a Course of Physics so complete and extensive as that which is designed to be taught in this University.

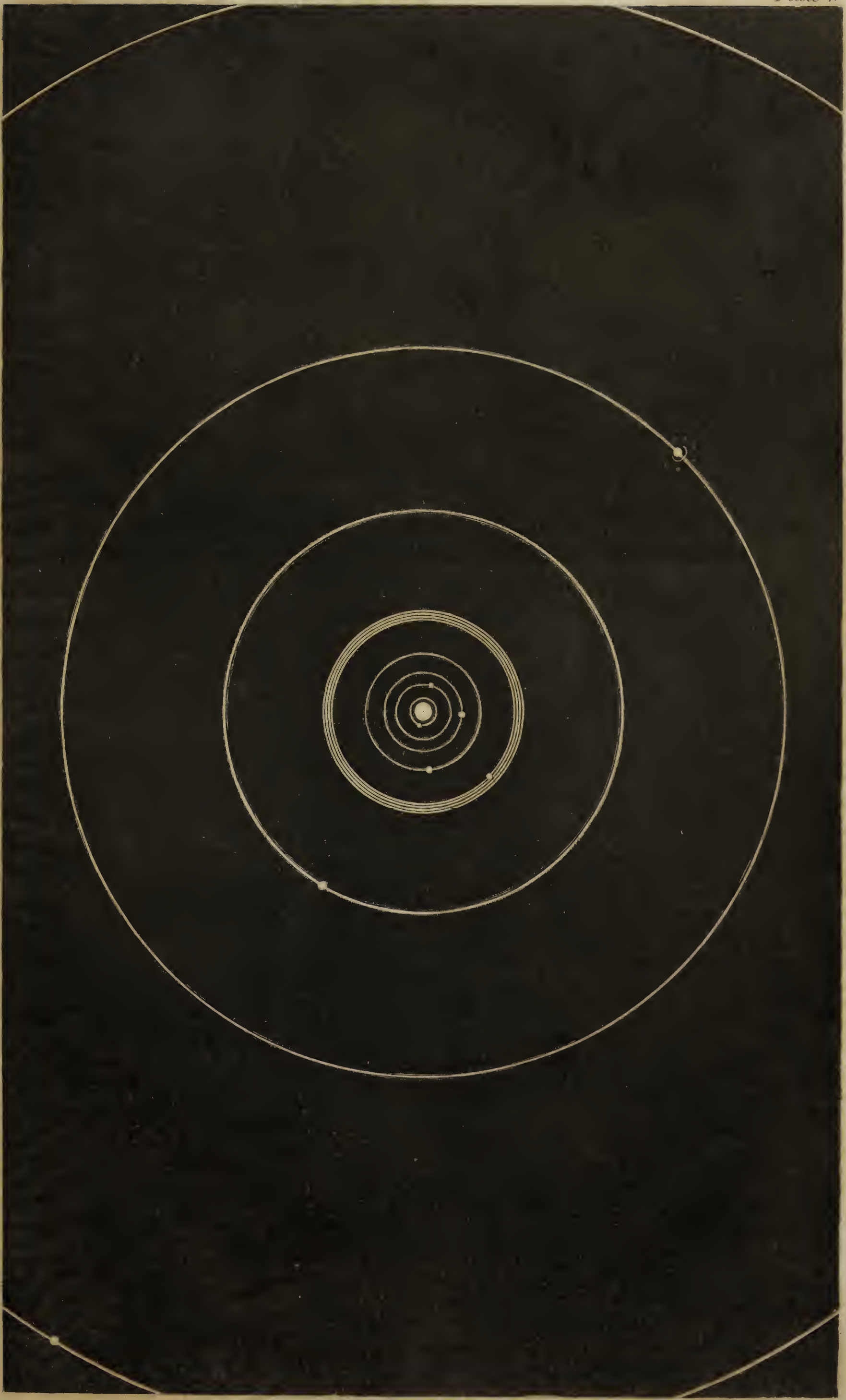
Electricity and Magnetism are the last subjects to which we propose to call the attention of the student. Although these branches of Natural Science have not yet attained maturity, still great advances toward that state have been made. The genius and industry of modern philosophers have not only accumulated a vast quantity of experimental results, but have actually brought one of these most subtle agents under the dominion of Mathematics. Electricity must now be considered as a branch of Mixed Mathematics, exhibiting analytical investigations, the beauty and refinement of which give it a title to be placed in the same rank with Physical Astronomy. The experiments which indicate the mutual relation of Electricity and Galvanism to Magnetism, will be subjects of careful examination; and with a view to this, a most effective system of apparatus has been prepared.

Such, Gentlemen, is a brief outline of the sciences to be taught in this school. I shall now endeavour to show why some or all of the topics which I have enumerated ought to form an essential part of a general as well as a professional education; to prove the advantage of such information in every situation of social and civilized life; and to demonstrate its absolute necessity in certain professions, in which it has been hitherto rather considered an accomplishment than an essential.

What, let me ask, are the main objects of a liberal education? Are they not to train and discipline the thinking faculty, to nourish and strengthen the reasoning principle, to impart vigour and courage to invention, to raise the tone of all the higher energies of the intellect,—in a word, to render tough and brawny the thews and muscles of the mind? And what exercise is so well fitted to attain these great ends, as that which is furnished by the investigations which are found in every department of Physics? In the experimental inquiries here instituted, the student is placed, in a certain degree, under the dominion of circumstances: his judgment is called into action; in his arrangements selection is necessary; manual dexterity, quickness of observation, and skill in the adaptation of means to an end, are all required and all exerted. The results, thus obtained, subsequently form the basis of a system of rigorously demonstrative reasoning, by which he is conducted with infallible certainty to remote and complicated truths. Habits of attention and accuracy never fail to arise out of this exercise; and, above all, the mind acquires skill to detect, and power to expose, a sophism, however ingenious the disguise, or plausible the form it may assume. Thus the discursive faculty is strengthened and sharpened, the judgment exercised and quickened, and that most valuable quality, common sense, never ceases to be engaged.

I shall perhaps be told, that although the objects to which I have just adverted include all those purposes of a liberal education which have direct and immediate utility, still that something more is necessary: that the mind, like the body, cannot be always in a state of full activity; that it must have its intervals of relaxation and repose; that subjects of elegant and pleasing meditation should be supplied to fill these intervals: and it will further be said, that the usage of elevated society demands grace and beauty of thought and expression, as imperiously as it exacts the same qualities in the external deportment of the body; that therefore it is an important part of a liberal education to store the mind with high contemplations, to inspire the soul with exalted sentiments, to fill the imagination with splendid associations, and to enrich the fancy with sublime imagery. These, I admit, are great and important objects, and, in certain stations and ranks, cannot and ought not to be dispensed with. The poets, historians, and orators of Greece and Rome, as well as those of a more modern era, the works of art in every age and country, have been studied with this view. Fertile sources these of the sublime and beautiful, and such as no one who values the estimation of the most refined and elegant society should overlook. But while I freely admit the sublimity of the classic volume, may I not be permitted to say, that objects not less lofty will be found in the pages of the book of Nature? While I confess the beauty of the works of man, shall I not assert the majesty of the works of God? Will it be affirmed that the highest aspirations of a poet ever even approached in sublimity the scenery of the universe unveiled in modern Astronomy? — Spaces and magnitudes of infinite extent, motions and forms of surpassing beauty; order, and harmony, to which the most refined result of human art is a mere mockery. To form an adequate notion of the splendour and sublimity of the prospects which will be spread before your mind, in this part of physical science, much more time would be necessary than can now be given to the subject. But still some faint idea of them may be caught even by a glimpse of the Solar System, and the stellar wonders, of which it is only a part, and in the comparison with which it shrinks into a point. The Sun, a body of enormous magnitude, is a centre, round which eleven worlds, similar to our own, but several of them much larger, continually revolve. (Plate I.) These orbs have their days and their nights, their summers and their winters, their lands and their waters, their hills and their vallies, their atmospheres and their clouds; and those more removed from the solar beam have their moons, in ever-enduring revolution, attendant on them. Is it supposable that they have not also their myriads of living creatures? Have they not their intelligent beings, capable of perceiving the laws of the universe, and therefore at once manifesting and glorifying the power, the wisdom, and the goodness of the infinite and incomprehensible Centre of all Existence? Are these rolling worlds like ours in all things else, and yet inferior to ours in that? Or is it not probable, that they are the habitations of classes of creatures excelling us as far in intellectual power, as some of those planets exceed ours in magnitude and apparent importance.

But it is not these speculations alone, supported as they are by the strongest analogies, and replete with materials for



THE SOLAR SYSTEM

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deep meditation, which fill us with admiration at divine skill. If we confine our views to those effects which are matter of certainty and not of speculation, we find ample scope for wonder. The worlds which compose the Solar System revolve in most complex and intricate paths, and are at first view subject to strange anomalies and irregularities; nevertheless, all these apparent discrepancies are resolved, after many ages, into the most beautiful regularities; for every deviation there is a subsequent compensation; and the smallest grain of sand does not move upon the surface of the earth without producing a corresponding effect in the remotest planet. Such are the wondrous laws which rule the universe,—laws which may truly be said to be the divine lineaments reflected from the bright surface of Creation.

If the contemplation of great magnitude fill the mind with sublime feelings, where else can such sources of those sentiments be found as are here offered? The Earth which we inhabit is but an insignificant part of the System. Yet its magnitude is so great, that it is by no means an easy task for the imagination to grasp it. Some notion may be formed of the largest mountain on the surface of the earth. But the earth itself is many thousand-million times this magnitude. If a pillar can be conceived whose base would cover a square mile, and whose height should be one mile, the bulk of such a pillar multiplied two hundred and fifty-thousand million of times, would be less than that of the Earth. And yet the Sun is nearly fourteen hundred thousand times the bulk of the Earth, and even several of the planets have some hundred times greater bulk.

Nor are the Velocities and Distances of these bodies less surprising than their magnitudes. The Earth moves in its orbit with a speed sixty times greater than that of a musket ball, and is at such a distance from the Sun, that this ball would take nine years to move from the one to the other.

Without pursuing further the consideration of the subject of the Solar System, although it is far from being exhausted, let us proceed to view that greater System of which our Sun with its attendant planets is only a constituent part. Viewing the firmament on a clear night, we behold numerous stars distinctly visible to the naked eye. We naturally inquire what are these? how are they placed with respect to our sun and planets? does any and what relation subsist among them? are they parts of the same system, or do they belong to different systems? We cannot here enter into the details of a discussion which would satisfy demonstratively these inquiries; but itmay be sufficient to state, that the Sun itself is a *Star*, one of a group or cluster of many hundred millions; that those stars of this group which are nearest to us are distinctly perceptible to naked and unassisted vision. These, however, are but few. Telescopic aid discloses many thousands more. In some directions they are so thickly placed, that neither the eye nor yet the telescope can separate them, and the firmament seems as though it were spread over with a brilliant starry dust.

I have spoken of the Solar System, and the distances and magnitudes of the bodies of which it is composed. I must now bid you suppose this *System* to shrink into a point, that you may stretch your imagination to the large conception of the Cloud of Stars, to which I have called your attention. To express the distance even of the Stars nearest to our System, we are compelled to use no common unit. Light is known to move with the almost unimaginable velocity of two hundred thousand miles in a second, and yet it can be proved that Light cannot take less than three years, to come from some of the nearest Stars to our System. From some of the most remote Stars of our group, it could not arrive in less time than fifteen thousand years! What wonderful inferences may we not draw from these facts! These Stars, and therefore the part of the universe to which they belong, must have been at least fifteen thousand years in existence. Again, it is probable, that some stars, created many thousand years since, are not

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NEBULÆ

yet visible, the first beam of light which they emitted not having reached us!

This starry mass, in which we are placed, has the form of a layer or *stratum*, the thickness of which is small, compared with its length or breadth. When viewed in the direction of the plane of its length and breadth, the stars, through which the eye is directed, appear numerous as to give a general cloudy whitishness to every part of the heavens in the direction of this plane. This produces that silvery band or zone which surrounds the heavens, and which is called the *milky-way*. Viewed in other directions, the number of stars is not so considerable. A general notion of the shape of this *nebula* may be obtained from the representation of it given in Plate II.

To carry our survey of the universe one step further.—This group of so many hundred millions of *Suns* (for Suns with attendant planets they undoubtedly are), immense as it is, is itself but a speck in Creation. Innumerable other groups, many of which far surpass this of ours in magnitude, surround us on every side through illimitable space. (Plate III.) From several of these *nebulæ* Light takes many millions of years to reach us. What notions do we not hence derive of the unbounded extent of Creation, not only in *space*, but in *time!*

When we refer to the era of our own creation, and compare the whole period from that time to the present, with the duration of one of these distant *nebulæ*, how utterly insignificant appears the particle of the universe on which we are placed; and how vain and foolish seem the records of the history of the human race! The greatest events which absorb the attention of man in the council and in the field, the eloquence of the debate, and the clang of the battle, dwindle into insignificance even more contemptible than the prattle of childhood or the hum of an insect. But still we must not forget that we measure these relations in reference to our own faculties, and that there is a Being whose powers are not limited by space or time, and who, while he contemplates the immensity of the universe, can, and does, keep constantly under his view, every the most trivial act of the most insignificant of his creatures.

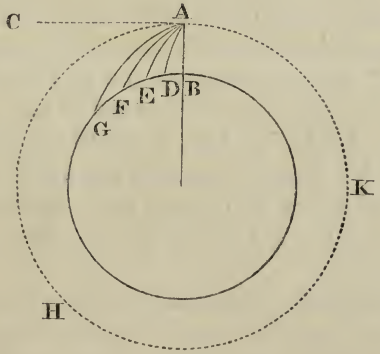
Having considered Physical Science as an element of general education, I shall now view it in relation to particular professions.

Among the various professions and avocations which the wants of man, natural and artificial, have called into existence, there are some in which an acquaintance with, at least, certain parts of Natural Philosophy, is pretty generally admitted to be essential; others in which it is rather considered as an acquisition to be desired, than a condition to be exacted, and others still in which it is never in any way looked for. Now, I shall endeavour to show, that in cases where its necessity is admitted, there is stronger reason for enforcing it than is generally supposed; that in many of the instances where it is only considered desirable, it should be rigorously exacted; and that in all cases where its absence is disregarded, its presence would be most useful.

A knowledge of the principles of Experimental Philosophy, has always been considered essential to Mechanics of every order and degree,—Engineers, civil, naval, and military,—Architects, and all who are engaged in arts and manufactures. It is hardly conceivable, that ignorance of the principles of Mechanical Science could for a moment be tolerated, much less defended, in any of those classes of persons. Nevertheless, it is certainly true, that even in this enlightened age, and still more in this country, the nursery of practical mechanics, those are to be found, who, without expressly denying the use of scientific knowledge to practical men, do indirectly discourage its cultivation. This is done by inveighing against what they call "theory," and converting "theorist," which, when rightly understood, is a title of honour, into a term of contempt; exactly in the same manner as the name "sophist" was brought into disrepute by its misapplication and abuse in the schools.

Theory, Gentlemen, in the sense in which it is received in the modern method of philosophising, is a term seldom rightly interpreted, except by those who have had the benefit of a well-disciplined academical education, and by none is it more completely misunderstood, than by those who suppose it useless or injurious in the practical applications of science. The hypothetical systems of the ancients, indeed, well merited this reproach ; but there can scarcely be a more gross manifestation of ignorance, than to attempt to fix such a stigma upon the Baconian Philosophy of our times.

In this system, Theory means nothing more than the grouping and classification of phenomena. As an instance, let us consider what is meant by the Theory of Gravitation. If a body placed at any point, A for instance, above the surface of the Earth, be deprived of support, it is observed to descend in a straight line AB, perpendicular to the surface, and to continue so to move until its progress is obstructed by that surface. This single fact is a mechanical phenomenon. But further observation and experience assure us, that had the body A been at any other part of the earth, a like effect would, under the



same circumstances, have ensued. These effects are then grouped together and form a class of phenomena, or a "mechanical law." We learn, also, that the like effect is produced at all accessible heights above the surface, and depths below it; that it is not peculiar to the body A, but is a common property of all bodies near the surface. Thus the class is enlarged, the law is extended. We have supposed that the body A, has been simply disengaged and permitted to fall. But suppose, that at the moment when it is so disengaged, it should receive an impulse in the direction AC. The body A will now no longer move along AB, but will be observed to take the curved course AD. By mathematical reasoning this effect is shown to be nothing more than the necessary consequence, or rather the immediate combination, of the former motion AB, and the impulse AC. In proportion as the impulse AC is increased in force, so in the same proportion is the range AE, AF, AG, &c. increased. And although we are unable directly to produce the effect, yet we can compute with the greatest exactness the force of the impulse which (exclusive of the resistance of the air) would actually enable the body to sweep entirely round the earth in the circular orbit AHK, in which it would continue for ever to revolve. All these phenomena, apparently so different from the direct fall of the body A, are nevertheless brought under the same class, and the law is called "terrestrial gravity."

Having embraced within the law the phenomenon of a body revolving round the earth, our attention is obviously drawn to the motion of the Moon, which is precisely of the same kind. Close examination soon convinces us, that it is only another variety of the same class of phenomena, and accordingly we say, "the Moon is retained in her orbit by the gravitation of the earth."

Having proceeded thus far in the process of generalization, the great discoverer of the Law of Nature directed his view to the Solar System. There he beheld several smaller bodies revolving in orbits round a greater central body, in exactly the same manner as the moon revolves round the earth. A presumption was immediately raised. The question was started, are these only further manifestations of the same law? Not contented, however, with taking the mere fact of the revolution round a central body as the basis of his classification, he considered it necessary to inquire into, and compare more particularly, the circumstances of the revolution. He computed from the Moon's motion in her orbit, the velocity with which a body placed where she is, would drop directly towards the surface of the earth. Upon comparing this with the velocity with which a body falls at the surface, he found a very remarkable relation, viz., that the velocity of the body at the surface, is as many times greater than the velocity of the body falling from the Moon's orbit, as the square of the distance of the Moon from the centre of the earth is, than the square of the distance from the body at the earth's surface to the centre. Here then was a test, a standard of comparison, a touchstone which must instantly betray the identity of the phenomena in question. Newton therefore proceeded to examine the planetary motions; and found, to his infinite pleasure, *that the velocity with which a body would drop from any planet to the Sun, was increased exactly in the same proportion as the square of the planet's distance from the Sun is diminished.* It is scarcely necessary to add, that the same law was found to prevail among the satellites, with relation to the several planets on which they attend.

Such is the THEORY of Gravitation, and let those who rail against theory examine it, and say whether they find any thing hypothetical, ANY THING NOT PRACTICAL in it. Similar EFFECTS (we inquire not of causes) are grouped and classified exactly in the same manner, as similar organised beings in Natural History; but this classification is attended with consequences of infinitely higher importance. To this generalization it is, that knowledge owes all its value. Without it our information would be reduced to scattered and unconnected facts, which, like separate filaments, would be utterly destitute of strength. If knowledge be power, it is because its threads are bound and twisted together in general theorems. And Theory, so far from being inconsistent with practice, is practice itself, and that in the most extensive meaning of the term. The theorist differs, it is true, from the practical man; for the one is conversant with facts collectively, the other individually. The one is a wholesale dealer in experience, the other only retails it.

Among the professions in which an acquaintance with Natural Philosophy has been viewed rather as an accomplishment than an essential, one of the first which claims our notice is the Medical. In the systems of education promulged by those who have been invested by the Legislature with authority to control and direct the preliminary studies of certain classes of medical practitioners, and to appoint the qualifications necessary to entitle them to be permitted to superintend the treatment and cure of the derangements of the human body, *we find no mention of physical Science.*[*] I shall not inquire from what cause this strange omission has arisen. An intelligent observer would infer that it proceeds from the assumption that no student could possibly overlook a qualification so obvious, and that it was omitted for the same reason that, in the catalogue of crimes denounced by the ancient laws, parricide was passed over as being an impossible act. Be the cause of the omission, however, what it may, it cannot be denied that the effect is injurious to the respectability of the profession, and must often be fatal to persons falling under the hands of those practitioners, who have not voluntarily acquired that which the competent authorities should compel them to know.

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[*] Of course none of these or the following observations are intended to be applied to those Universities which require a degree in arts as a preliminary to the medical degrees.

I believe, Gentlemen, I am justified in asserting, that such an error as this is without a parallel in any system of professional education; for, if there be one avocation which more than another demands a knowledge of the laws and phenomena of Mechanical Science, with which all its laws, in all its branches, are intimately connected, and in which they are practically applied, it is that art which has for its object to maintain in constant repair the most wonderful and most perfect of all machines,—the Human Body. Physical Science, Gentlemen, is the corner-stone of the arts of Medicine and Surgery. There is not a department of it, not an element, not a law, not a phenomenon, which does not find a practical illustration in the structure and functions of the Living Animal.

I should be going too far in the sacrifice of truth to courtesy, were I not here, in the capacity of a public teacher, and placed as I am under a serious responsibility, to lift my voice against this defect of the system of Medical Education in these countries. I do assert boldly, and will maintain confidently, that *this system is, and must continue to be insufficient, until the Elements of physics constitute an integrant, essential, and indispensable part of it.* In this opinion I am happy to say, that I am confirmed by my medical colleagues, and by none more strenuously than by that eminent physiologist* who addressed you on the opening of the Medical School. And here, Gentlemen, I ought to acknowledge, that although Physical Science *be* rejected by the public authorities, as a condition of admission to practice, yet there are numerous and respectable practitioners who have cultivated it very extensively. But if they have made that valuable acquisition, if they have elevated themselves in their own estimation, and in that of society, by raising their knowledge more near to the level of their high profession, to whom are they indebted for that distinction? Do they owe it to the good discipline of their early education, or to the excellent rules and institutions of the privileged school from which they have obtained their diploma? Or is it not rather due to their own judgment in perceiving the inconsistency, and perhaps to their own conscience in feeling the dishonesty, of practising an art without learning its principles?

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* Charles Bell, Esq.

I have said, Gentlemen, that the science of Physiology rests upon that of Physics as its foundation, and not on one part only of Physics, but on each and every of its subordinate branches. Let us now see how far facts will bear me out in this assertion. I shall begin with the skeleton. Here is a *Machine* in the strictest sense of the term. Every part is adapted to transmit certain motions and forces to other parts properly formed to receive and modify them. Levers, hinges, and joints are fitly arranged, some to sustain pressure, others to transmit active force; some having a limited range of action, others having a larger sweep, and greater velocity; some capable of moving in one direction only, others capable of moving in all directions, and furnished with an universal joint. Still more conspicuous are the perfection and beauty of this machine, were we to consider it in reference to the adaptation of its various parts to the ends they are destined to attain. Limited as I am on the present occasion, it would be quite vain to attempt to descend to further particulars. I trust, however, ere long, to make this exquisite structure not the subject of one, but of several mechanical lectures. It may, nevertheless, be proper to observe, that it is not merely in the form, arrangement, and connection of the Bones that mechanical principles are illustrated and applied. The internal structure and arrangement of the material of these parts present the most remarkable exemplification of mechanical laws.

In cases of derangement or dislocation, the problem presented is, to determine the best method of adjustment: where and how a force may be applied with the greatest mechanical advantage, and with the least risk of injury?

In such a case machines are to be selected or invented for the due application of the force; and even though such instruments should be obvious, the use of them may be attended with disastrous results, if attention be not given to their mechanical effects. A pulley might be used, which by a very slight application of manual force would tear off a limb. The want of mechanical knowledge in the surgeon, cannot be defended by saying that he may resort to the engineer; unless the engineer be also an anatomist, he cannot assist him: to contrive the machine, it is necessary to know minutely the structure, form, and strength of the parts to which it is to be applied, as well as the exact quantity of motion or force which must be produced. But, indeed, the necessity of mechanical knowledge in the selection, invention, construction, and use of surgical instruments, and in all surgical operations and inquiries, is so very obvious, that it is almost an insult to your understandings to dwell upon the subject; and it is lamentable to think that even an allusion to it should be called for at this time and in this place.

If the mere skeleton exhibit such multifarious illustrations of physical principles, what shall we say, when the sinews, tendons, muscles, nerves, veins, arteries, integuments, skin, and all the concomitant apparatus of the organized body are added? The mere skeleton is a machine, it is true, but it is one, whose properties and functions are explicable on the statical and dynamical principles of what is technically called an *invariable* system, the most simple form in which bodies can be mechanically considered. The sinews, tendons, muscles, and nerves, on the other hand, are *variable* systems, require the application of different reasoning, and fall under a different branch of the science. Partial rigidity, imperfect flexibility, tension, contraction, and elasticity, are here to be considered. It is in the last degree absurd, to suppose that we can have any distinct ideas of the powers and the action of those parts of the body, without having at least a general acquaintance with that part of Physics which treats of the forces which I have just mentioned. It would seem almost an offence against the common sense of my hearers, were I to insist on proving that the action of the vascular system involves *hydrodynamical* principles; that the organs of respiration are *pneumatical;* that the oral and vocal organs are constructed on the principles of *acoustics;* that the principles on which the structure of the eye depends, cannot be intelligible without learning *optics;* that *capillary attraction* determines, in a great degree, the functions of all the pores, and of those delicate tubes called hairs. In fact, Gentlemen, it is impossible to look for a moment at the animal body, or any part of it, without observing the illustration of some scientific principle: every joint is a physical theorem, and every limb is a volume of mechanical philosophy.

Impressed as I am with a deep conviction of the importance of this subject, I would appeal to the good sense of those highly gifted men who hold the reins of medical education in this great metropolis, and not to them alone, but to those not less distinguished persons who exert the same control in Scotland and in Ireland. I would adjure them, by the high nature of their profession,—a profession which is raised still higher by their own talents and attainments, —I would implore them to efface from its most humble follower the stigma of ignorance. I would bid them behold the medical schools of France, of Holland, of Italy, and other not less eminent institutions of Europe, where Physics are acknowledged to be as indispensable to the medical student as Anatomy itself; I would bid them not behold alone, but imitate. Let all who seek any licence or diploma, have received at least the elements of liberal knowledge. Such an improvement is demanded by the spirit of the age, and in this country, thank heaven! that spirit will not, and cannot be resisted.

Gentlemen, it is proper here to notice two objections which have been urged against considering the human body as a machine. Although these objections come from very different classes of persons, and are insisted on from very different views and motives, yet both originate in the same misconception, and are refuted by the same argument. One of the objections to which I allude, originates among Physiologists, some of whom misapply those laws which are called the laws of life, or vital principles: by this abuse those laws become strictly what, in the hypothetical system of philosophizing, were called *occult causes*. These persons conceive, that the solids and fluids composing the living organized body are not, like all other solids and fluids, amenable to the established mechanical principles; in fact, they would have us suppose that matter, when organized and endowed with the living principle, changes its nature, loses its properties, and ceases to be itself.

The other objection to which I have referred, comes from some who, actuated by a most praiseworthy zeal to support the purity and spirituality of religion, are apprehensive that if the application of mechanical reasoning respecting the human body be once admitted, it will end in an attempt to trace *life* itself to Mechanism, to destroy the cheering prospects and annul the virtue-breathing precepts of Revelation, and substitute in its place a gloomy and heartless Materialism.

To all these objectors, of whichever class, I make one and the same answer,—" study Mechanical Science." The superficial physiologist will there learn how unphilosophical it is to assume, that matter in different arrangements obeys different and inconsistent laws, and he will become convinced that such an hypothesis is as untenable as it is unnecessary. The zealous professor of a pure religion will be taught, that so far from mechanical reasoning having a tendency to prove that the body derives the principle of life from its own mechanism, all the analogies take a diametrically opposite direction, and demonstratively establish the impossibility of such a phenomenon.

That you may not receive this assurance merely as a dictum, let us consider what constitutes a Machine, whence it derives its virtue, and what are its objects? A machine is *a combination of parts composed of material substances, solid or fluid, or both, as the case may be, having certain definite forms and arrangements, and possessing certain capabilities of transmitting force or motion.* Its objects are to move, press, sustain, combine, divide, or otherwise modify, those substances to which it is applied. But the machine itself, merely as such, cannot accomplish this. It possesses not its own principle of motion; it cannot urge its own levers, or stretch its own cords, or turn its own wheels, or put its own fluids into circulation. The application of some efficient cause extrinsic to, and altogether distinct from the machine itself, is necessary to accomplish this. This extrinsic cause, whatever it be, from which the machine derives its motion and efficacy, is called the *prime mover.* The point on which I desire now to fix your attention is, that this prime mover is altogether distinct from, and independent of, the machine; that it possesses, or at least may possess, no property in common with it, and that its existence or non-existence is not decided by the existence or non-existence of the machine. The machine may be broken, destroyed, worn by age, or otherwise disabled, and yet the prime mover may still retain its original energy. Thus a steam-engine is moved by fire, a mill by wind or water: the steam-engine may deteriorate by age, and the mill be broken to pieces by accident, and yet the fire, and the wind, and the water, will still preserve their powers. Now, Gentlemen, these observations, which I think correctly describe a Machine, may, *mutatis mutandis,* be applied to the Human Body. This body is also "a combination of parts composed of material substances, solid and fluid, having certain definite forms and arrangement, possessing certain capabilities of motion and force," destined and admirably adapted to obey the dictation of its Prime Mover, the living principle, the immaterial spirit. So long as it pleases the great Engineer who constructed this body, to permit its connection with that intellectual spirit, so long will it obey the impulses which it receives; nor does the decay of this Bodily Machine infer any corresponding decay in the moving Spirit, any more than the wear and tear of a Steam-engine proves the destruction of the principle of Heat which gives it motion. Neither are we to infer, because this Bodily Machine in its obedience to the Vital Spirit acts mechanically, and follows all the ordinary properties and laws of Matter, that, therefore, the Spirit which moves it partakes of the nature of Matter, or is amenable to its laws, any more than we should infer that the levers, wheels, pumps, chains, cords, and valves of a Steam-engine are regulated by the laws which govern Heat. On the contrary, I submit it to the candour of the most sceptical materialist, whether the whole tendency of analogy does not directly overthrow the hypothesis that the principle of life is organic. We are told in THAT BOOK,* of which both Christian and Jew equally acknowledge the authority, however they may otherwise differ, that, in the first instance, "God formed man of the dust of the ground;" that is to say, he created that curious and beautiful machine, the organized Human Body—but that body was still an inert structure without the principle of motion or spontaneity; a more noble work remained to be performed, the immaterial spirit, the divine essence, *the prime mover* of this machine was to be applied, and accordingly we learn that God "breathed into his nostrils the breath of life," and then, and not till then, "MAN BECAME A LIVING SOUL."

The province of the Physiologist, connected with Mechanical Science, seems to be sufficiently definite. He will first learn the physical laws which regulate the changes incident to matter, in the various forms which it may assume, and situations in which it may be found; he will acquire an exact knowledge of the various forces of Attraction, Affinity, Aggregation, Repulsion, or the classification of effects by whatever name it may be expressed. With patient accuracy, unbiassed by prejudice, and uninfluenced by preconceived hypotheses, he will observe the phenomena exhibited in the Human Body, and compare them with the established laws of Physics. He will refer each phenomenon to its proper class, or, as the phrase is, account for it. In such an investigation many appearances ought to be expected, which will seem at first, and perhaps for a very long period, anomalous. Such phenomena must be held *sub judice*, and reserved for more careful examination and more mature reflection, until some link be discovered which connects them with a known law, or until they exhibit some characters by which they may themselves be grouped into new classes. But we must not deceive ourselves, and fancy that we have terminated the inquiry, when we have given, to what we cannot comprehend, the title of "Laws of Life."

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* This appeal to Scripture is made, not of course to refute the sceptic who rejects it, but to show the believer that all which has been urged is consistent with it.

There is one inducement to the study of Animal Physics, which should urge the Natural Philosopher to study Physiology, as strongly as it must tempt the Physiologist to become acquainted with Mechanical Philosophy. It has been suggested by an eminent French Mathematician,* that a view of the Animal Organization, in reference to the physical laws by which it is regulated, would be the most sure and successful means of improving and extending Mechanical Science, and that an abundant harvest of honourable fame awaits him who combines the different kinds of knowledge requisite to accomplish this. The same idea has, with his usual felicity and success, been expressed by the enlightened author of "Animal Mechanics." To insist upon the value of this suggestion is superfluous, if we only look back to past inventions and discoveries, and compare them with what we already know of the animal structure. Had the Eye been carefully studied, it could not have failed to lead directly to the discovery of achromatic lenses, for it is itself a most perfect achromatic instrument, and it owes that quality to the same principle which gives perfection to the telescope. The same organ would readily have suggested the means of removing or diminishing spherical aberrations; and without a great stretch of mind would have pointed out the Periscopic Glasses invented by Dr. Wollaston.* May we not reasonably look forward to further successful results from the examination of the eyes of all species of animals? The vocal and oral organs may furnish vast improvements in Acoustics. The Galvanic effect produced by certain animals may, when duly attended to, add further force to that already powerful agent. A view of the Animal Creation furnishes such subjects without end, and why should it astonish us that the most certain and effectual means of improving our own skill should be, to imitate the works of Him whose hand cannot err?

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* Biot.

It would be quite vain, within the limits of this lecture, to attempt any further details on the mutual connection of Physiology and Physics. For the present, I venture to recommend, not to medical men only, but to all my auditors, the perusal of that most eloquent and philosophical tract published by the Society for the Diffusion of Knowledge, and entitled "Animal Mechanics;" an essay which no one can read without becoming a wiser, and what is more, a better man.

Having trespassed already so largely on your indulgence, I shall only allude to the advantages of the knowledge of this science in the Council, in the Senate, at the Bar, and in the Pulpit. In these professions, it is not merely as an element of liberal knowledge that its benefits will be felt. Questions will be started, measures proposed, and discussions raised, in which ignorance of the elements of Physics will lead to the greatest difficulties and embarrassments. In a country like this, which owes its place in the scale of nations, in so great a degree, to its arts and manufactures, how often will the statesman and the senator have to decide on measures, the policy of which must depend on the principles of this science—measures in which the social existence of millions may be involved? In such a country, how often is the advocate called upon to plead a cause in which the property and subsistence of his client hinges upon a mechanical question? And in any country when infidelity erects her crest, and levels her fury against religion, what more ample shield can the minister of God spread over the altar, than that which reflects the splendour of God's own works.

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* Although the neglect of the natural aids to the improvement of science may have retarded the progress of knowledge, yet it enhances the merit of inventors, by having increased the difficulties of discovery.

THE END.

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